PARK BASINS PROVINCE (038)

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With a section on Upper Cretaceous Niobrara Fractured Calcareous Shale Oil by Richard M. Pollastro

The Park Basins Province of Colorado covers approximately 6,900 sq mi (Maughan, 1988) and includes all of the counties of Jackson, Grand, Summit, Gilpin, Clear Creek, and Park. Much of the province consists of Precambrian granitic and igneous intrusive terranes unlikely to contain significant quantities of hydrocarbon.

Areas prospective for hydrocarbons are the north-south-trending Laramide-age structural basins of North, Middle, and South Park, as well as the Blue River Valley, a total area of approximately 2,700 sq mi. This area is bounded on the east by the Never Summer Range, Medicine Bow, Tarryall, and Puma Mountains of the Front Range, on the south by Thirtynine Mile Mountain, on the west by the Mosquito, Gore, and Park Ranges, and on the north, by the south end of the Laramie Range, Independence Mountain, and the Sierra Madre. The Park Basins area was a positive structural feature through much of the Paleozoic (Tweto, 1980), and developed into an elongate basin or basins during the Mesozoic. Late Mesozoic and Tertiary intrusives and volcanics in Rabbit Ears Range created the two separate physiographic basins of North Park and Middle Park, while uplifted Precambrian crystalline rocks and the late Mesozoic and Tertiary intrusives of the Williams Fork and Vasquez Mountains separate Middle Park from South Park. The margins of the Park Basins are characterized by high-angle reverse faults on the east and high-angle normal and reverse faults on the west (Maughan, 1988).

All of the Park Basins Province's commercial production of oil, gas, and CO_2 comes from structural and combination traps in the faulted basin-margin anticlines of North Park Basin in Jackson County. North McCallum field, the first discovery, has accounted for more than half the oil production in the province. Continental Oil Company's Sherman A-1 discovery well on North McCallum Anticline was completed in 1926 for an estimated 30 MMCF of CO_2 and 500 barrels of 46° API gravity condensate per day but was produced only intermittently between 1926 and 1943 (Carpen, 1957a). Since this initial discovery, 566 wells have been drilled. Activity increased with discoveries of the Coalmont (1951), Battleship (1954) and Canadian River (1956) fields but has since waned because of the relatively small size of these and later discoveries. There were significant shows in Middle and South Parks, and South Park Oil Company's State 1 tested 5 MBO from a thin Pierre sandstone on Rieneker Ridge in South Park in the 1930's (Clement and Dolton, 1970), but no commercial production has been established. Four fields have produced over 1 MMBO in North Park Basin. In 1991, 81 wells produced hydrocarbons in North Park Basin. The 198,639 BO produced in 1991 was 0.6 percent of the total oil production for the State of Colorado. Cumulative oil production for the province from 1926 through 1991 is 15,793,106 barrels (Colorado Oil and Gas Conservation Commission, 1991) or about 1 percent of cumulative oil production for the State of Colorado.

Gas production from the Park Basins Province for 1991 was 211 MMCF which is 0.07 percent of the total 1991 gas production for the State of Colorado. Cumulative gas production for the province is 11 BCF (primarily from the Canadian River field) (Colorado Oil and Gas Conservation Commission, 1991) or 0.17 percent of the total gas production for Colorado.

Carbon dioxide is also produced in the province. Production for 1991 was 1.4 BCF (Colorado Oil and Gas Conservation Commission, 1991) or 0.49 percent of the State total and cumulative is 672 BCF or 25 percent of the State total.

Although the Park Basins can be described as a mature petroleum province, it is reasonable to expect further discoveries in small traps that are difficult to evaluate without drilling, owing to the complex structures of the province. The reprocessing of old seismic data and the use of 3-D seismic should help considerably in identifying small structures similar to those found at the Lone Pine field (Wellborn, 1983a). Many of the traps we see today likely were created after generation and migration of hydrocarbons had occurred, particularly in South Park Basin, where many Laramide structures formed later than in North Park Basin (Sawatzky, 1972).

Although no pure stratigraphic plays are producing in this province and little exploration effort has been directed toward identifying this type of target, stratigraphic traps controlled by onlap and porosity pinchouts may be present. Again the best prospects are in North Park, where the Cretaceous section is thickest and burial was deepest; significant opportunity may remain in South Park Basin where few exploratory wells have been drilled.

Two conventional plays were assessed, the Cretaceous-Upper Jurassic Structural Play (3801) and Subthrust Play (3802). An unconventional continuous-type play, Upper Cretaceous Niobrara Fractured Calcareous Shale Oil Play (3803), is also described by Richard M. Pollastro.

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CONVENTIONAL PLAYS

3801. CRETACEOUS-UPPER JURASSIC STRUCTURAL PLAY

The characteristics common to the accumulations of this proven play are similar traps and stacked reservoirs. Late Laramide thrusts formed north-south-trending, faulted basin-margin anticlines in all three basins (Wellborn, 1977). Most structures with surface expression have been tested and production from these structures accounts for virtually all the oil and gas production in the province. While several fields have combination structural and stratigraphic traps, all producing fields contain a structural component. The play is generally inclusive of those portions of North, Middle, and South Park Basins that contain Upper Jurassic through Cretaceous rocks with the greatest potential in Cretaceous Dakota Group reservoirs on the basin-margin faulted anticlines of North Park. Similar traps may be concealed by the Rabbit Ears Range volcanics between North and Middle Park where there have been shows, and the Thirtynine Mile volcanic field in South Park, but to date no wells have produced from beneath these volcanic fields.

Reservoirs: Producing reservoirs are the Upper Jurassic Morrison Formation, the Lower Cretaceous Dakota and Lakota Sandstones, the Lower Cretaceous Muddy Sandstone, the Cretaceous Niobrara Formation and Pierre Shale, and the Frontier Formation.

The Upper Jurassic Morrison Formation, which consists of alluvial and lacustrine mudstone, siltstone, limestone, and sandstone, produces at North McCallum field. Reservoir thicknesses range from 15 to 140 ft with average porosities of 15.7 percent and average permeabilities of 31 mD (Maughan, 1988).

The Lower Cretaceous Dakota Sandstone, the most prolific reservoir, consists of intertongued beds of fluvial shoreline sandstone, conglomeratic sandstone, carbonaceous siltstone, claystone, and occasional thin coals. Reservoir thicknesses average 25-40 ft, with an average porosity of 18 percent and average permeability of 70 mD (300 mD max). The Dakota Sandstone has produced at Alkali Lake, Battleship, Canadian River, Delaney Butte, Lone Pine, North McCallum, South McCallum, and Michigan River fields.

The Lower Cretaceous Lakota Sandstone consists of buff medium-to coarse-grained sandstone and conglomerate. Reservoir thicknesses average 70 ft, with an average porosity of 18.5 percent and average permeability of 100 mD (450 mD max). The

Lakota Sandstone has produced at Battleship, Canadian River, Delaney Butte, Lone Pine, North McCallum, South McCallum, and Michigan River fields.

The Lower Cretaceous Muddy Sandstone consists of white to tan very fine grained sandstone. Reservoir thicknesses average 30 ft, with an average porosity of 24 percent and average permeability of 300 mD (Carpen, 1957). The Muddy Sandstone has produced at Canadian River, North McCallum, and South McCallum fields.

The Niobrara Formation consists of thin-bedded calcareous claystone with limestone at the base. Reservoir thicknesses average 25-35 ft, with an average porosity of 33 percent and average permeability of 0.1 - 1.0 mD. The Niobrara Formation has produced at Canadian River, Carlstrom, Coalmont, Delaney Butte, Grizzly Creek, Johnny Moore Mountain, North McCallum, South McCallum, and Michigan River fields.

The Pierre Shale consists of dark-gray to brown fissile claystone or mudstone, occasional beds of sandstone, and limestone, and thin beds of bentonite. Reservoir thicknesses average 20 ft, with an average porosity of 14 percent and average permeability of 7 mD. The Pierre has produced from North McCallum and South McCallum fields.

Frontier Formation reservoirs are very fine grained fractured sandstones which form a continuous blanket across the basin. The average reservoir thickness is 35 ft and average porosity is 20 percent (Welborn, 1983b). The Frontier Formation has produced from Battleship, Butler Creek, and Delaney Butte fields.

Source rocks: The Lower Cretaceous Mowry Shale has probably the best source rock potential (Filmore, 1986) and has been identified as a primary source rock in the adjacent Greater Green River Basin. The Mowry Shale was deposited during the second major Cretaceous sea transgression and is a dark-gray to black laminated siliceous mudstone that has bentonite beds throughout and occasional thin interbedded sandstones, and siltstones (Filmore, 1986). Mowry rocks in the deepest part of North Park have vitrinite reflectance values (R_o) within the thermal zone of oil and gas generation and TOC values averaging 1.5 percent (Filmore, 1986). In South Park Basin the Pennsylvanian Belden Formation is a possible source rock, but surface vitrinite values for the Paleozoic rocks that are exposed along the east flank of the Mosquito Range are generally overmature (Bostick and Pawlewicz, 1984). Pierre rocks in the Elkhorn subthrust on the east side of South Park Basin have thermal maturities within the zone of oil generation but are not rich in organic material (data on the Hunt Federal No. 1-17 Tarryall subthrust well produced by Edelman, Percival and Associates). Burial history plots (Filmore, 1986) and (Maughan, 1988) for North Park Basin indicate maximum burial depths of 20,000 ft and suggest that expulsion of hydrocarbons occurred approximately 45 to 40 Ma. Migration was over short distances vertically and updip through open fracture systems, and along bedding planes.

Traps: Oil and gas were trapped in late Laramide structures (anticlines and faulted anticlines) and combination structural and stratigraphic traps (onlap pinch-outs). The trap sizes are generally small, but reservoirs are relatively thick or stacked. An example is the Lone Pine field, which has produced more than 2 MMBO from approximately 160 surface acres (Wellborn, 1983c). Seals are primarily low permeability shales and fault truncations.

Exploration status and resource potential: Since the mid 1980's little drilling activity has taken place in this play in the Park Basins. The lack of test wells is probably because of the very limited success in finding fields of any size since the mid-1970's. The least explored areas with potential fields over 1 MMBO are Middle and South Parks along the basin margins and adjacent to thrusts.

Although the resource potential is not fully developed, the prospect of finding large fields is poor. While Middle Park and South Park are probably under-explored, thermal maturities are not as high, and the Jurassic and Cretaceous sections are not as thick. In South Park Basin, the Laramide deformation occurred later than in North Park, therefore, the traps may have formed during or after the late stages of hydrocarbon generation. While there have been many shows in the basins, TOC values are low, and oil and gas may not have been generated in sufficient quantities for large-scale expulsion to occur.

Estimates of oil and gas yet to be discovered were based partly on exploration, discovery, and production histories. Estimates of total oil and gas generated and trapped, remaining prospective areas, and success rates were also considered.

3802. SUBTHRUST PLAY (HYPOTHETICAL)

This hypothetical play occurs under Laramide thrusts where preexisting traps were preserved beneath the thrust or where the overthrust Precambrian rocks formed a trap in conjunction with a thick low-permeability shale seal. Thrust faults having throw sufficient to create or preserve traps of 1 MMBO are the Independence Mountain Thrust, which displaced Precambrian rocks south as much as 12 mi over the Paleocene and Eocene Coalmont Formation of North Park (Blackstone, 1977); the Williams Fork Thrust on the east side of the Blue River Valley where Precambrian rocks of Williams Fork Mountains are thrust westward over the Pierre Shale; and the Elkhorn Thrust on the eastern margin of South Park Basin where Precambrian rocks are thrust to the west over the Tertiary Denver Formation and older rocks (Sawatzky, 1972). The rocks under these thrusts are adjacent to, and in most cases a continuation of, the rocks in the Cretaceous-Upper Jurassic Structural Play (3801). Potential reservoirs are differentiated only by trapping mechanisms and greater burial depths. The source rocks again are the same as in play 3801 with potentially higher maturity levels resulting from increased heating in the subthrust. Oil and gas may be trapped by the thrusts themselves or by Laramide structures (anticlines and faulted anticlines) and combination structural and stratigraphic traps preserved under the thrusts.

There has been interest in the subthrust play for decades, but the first actual test was the recently drilled Hunt 1-17 Tarryall in the N1/4N1/4 of sec. 17, T.10 S. R. 75 W. which cut through the Elkhorn Thrust east of South Park and reached a total depth in the Pierre Shale of approximately 12,700 ft. The Pierre Shale in the Hunt 1-17 is marginally mature to very mature, organically lean for oil, and gas-prone. The well had gas shows, but the R_o values were high with respect to oil generation at total depth.

The possibility of finding a 1 MMBO or a 6 BCFG or larger field is a reasonable one. Resource estimates are based on extent of potential reservoir rocks within the play and source rock potential.

UNCONVENTIONAL PLAY

3803. UPPER CRETACEOUS NIOBRARA FRACTURED CALCAREOUS SHALE OIL PLAY (HYPOTHETICAL)

By Richard M. Pollastro

The Niobrara ranges in thickness from about 500 ft in South Park Basin (Stark and others, 1949) to as much as 800 ft in North Park (Hail, 1968) and varies in lithology from fissile-bedded, dark gray calcareous shale (Maughan, 1988) to more brittle micritic limestone and marl (Vincelette and Foster, 1992). Burial history reconstructions in North Park by Fillmore (1986) for the Lower Cretaceous Mowry Shale, which lies about 400 ft below the Niobrara, indicate maximum burial depths near 20,000 ft.

The organic-rich Upper Cretaceous Niobrara Formation produces some oil and gas in fields of the North Park Basin from fractured calcareous shale or marl. Although several oil shows have been reported and non-commercial tests have been performed in Niobrara or equivalent strata from the Middle and South Park Basins, no commercial production has been reported. All production in the Park Basins Province is from structural and combination traps in faulted basin-margin anticlines in Jackson County, Colorado. Oil and gas production from fractured Niobrara are reported from nine of the thirteen fields in North Park. Three of these fields, Carlstrom, Coalmont, and Johnny Moore Mountain, report production from only the Niobrara Formation (Maughan, 1988). API gravities of oils produced from the Niobrara in these fields are between 37¡ and 54¡, as reported by Fillmore (1986). Cumulative production from fractured Niobrara in the North Park Basin as of July, 1993, was about one quarter million barrels of oil; the GOR is 625.

Prolific, self-sourced oil is produced from fractured, cyclic-bedded, organic-rich units of the Niobrara in the northeastern portion of the Denver Basin to the east of Province 38, and along the eastern portion of the Sand Wash Basin to the west. Thus, similar organic-rich Niobrara in the more central Park Basins Province should also have good petroleum potential assuming that similar burial conditions are met and favorable structural and trapping elements exist for economic commercial oil production. Geochemical analysis of cuttings from the Hunt Oil Company Federal No. 1-17 Tarryall well, Park County, in South Park Basin (Core Laboratories Report, 1992) from depths of 5,600 ft to 12, 700 ft have vitrinite reflectance values ranging from 0.5 to 1.5 and total organic carbon contents ranging from about 0.1 to 1.5. Although some oil-generating potential is evident from the burial history and geochemical analysis of the Niobrara from test wells in various areas of the province, no new fractured reservoir systems have been identified and the play probability for this play was assigned a 0.1; therefore, the play was not assessed.

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